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Influence of Lime on Lime Soil Stabilization on Natural Occurring Acidic Soil Engineering Properties

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Abstract

The need to intervene in improving the structural stability of soils arises so as to bring about stability. One of the intervention which has been used and still in use involves the application of lime to soil so as to enhance the stability in the soils. Investigations into the properties of lime treated (lime-soil stabilization) soils seeks to assess the suitability of soil tested for its suitability for usage. Using lime to stabilize soil has a number of benefits, among many, decrease in soil plasticity index, increase in soil strength, increase in durability, decrease in swell potential and volume change of the treated soil, add to the list. In the construction industry, the use of lime to soil is associated with weak, unstable or unsuitable soils. Soil referred to may be natural or imported natural occurring soil encountered during road construction for base courses or other.

An experimental program was undertaken to investigate the effects of hydrated lime on natural occurring acidic soil engineering properties. Three (3) natural occurring acidic soil samples were collected from three different locations and treated with different lime contents (i.e. 2%, 4%, 6%, 8% and 10% by weight of soil). Laboratory test such as soil gradation, consistency limits, compaction, Unconfined Compression Strength (UCS) and California Bearing Ratio (CBR) tests were conducted. The UCS and CBR tests were carried out after 7 days curing time. The test results indicated that the inclusion lime reduces the plasticity of the soil. The results of this investigation have shown that beneficial effects are obtained by the addition of lime contents to soil samples. The dry density of the soil sample decreases with increase in lime content. For UCS indications are that lime stabilized material for sample 2 at each lime content with highest strength recorded at lime content of 10% after curing for seven days with CBR tests for soil samples treated with different lime contents reporting constant increase when compacted at 55 comp active efforts.

Keywords: Lime; index soil properties; engineering soil properties; unconfined compressive strength; CBR

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1. Introduction

1.1Literature review

Alternative method of improving the engineering properties of soils is the addition of chemicals stabilizers or other materials to improve existing soils. Chemical stabilization is achieved by mixing chemicals - such as lime - with soils to form a stronger composite material [12]. Soil stabilization is referred to as the process of the alteration of the soil properties (i.e. geotechnical properties) to satisfy the engineering requirements [4, 10, 15, 21, 23, & 26]. Different kinds of stabilizers are used as soil additives to improve properties of soils tested. Stabilizers, such as lime, have been used in the past and this is as a result of their chemical reactions with soil in the presence of water [2, 5, 9, 13, 14, 16, 20, 22, & 25].

Civil engineers as well as soil scientists perform soil investigations with the intention to get information pertaining to the physical properties of soil so as to understand its behavior using lime to soil improves the physical condition of the soil. The influence of lime stabilization on engineering properties of soils can be classified as immediate and long-term modification benefits ranging from the change in soil texture, the reduction of soil swelling characteristics to the apparent reduction in clay content of soil and other [22].

When lime is applied to acidic soils it decreases acidity by increasing the pH thus impacting the soil properties [8, 1, 19, & 22]. Formations of cementitious compounds such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) promotes the development of strength due to soil-lime reactions i.e. colloidal and pozzolanic reactions etc.

In a study by [18] which explores the engineering properties of the soil as conducted in Maastrichtian in Nigeria and as it was necessitated by State government of Nigeria. Among parameters/properties measured were grain size, atterberg limits, compaction, shear strength, permeability and porosity as well as bulk density. The result indicated high strength in the soil tested.

2. Materials and methods of testing

2.1. Sample preparations

Bags of naturally occurring acid soils were collected from Umlazi, a township on the east coast of KwaZulu-Natal, South Africa, located south-west of Durban (29°58′S 30°53′E), Scottburgh is a coastal situated on the mouth of the Mpambanyoni river (30°17′S 30°45′E) and Amanzimtoti, (26.2 km South of Durban in South Africa. Soil samples for laboratory analyses were typically air dried and pulverized to provide a stable homogeneous mixture.

2.2. Tests conducted on soils

Test such as sieve analysis, consistency limits (Atterberg tests), Maximum Dry Density and Optimum Moisture Content determination, Curing Soaking- for CBR penetration, CBR Penetration was performed. These tests were conducted in relation to Technical Methods of Highway 1 [6] under subsections, method A2, A3, and A4.

3. Results and discussion

3.1Index properties

Soil properties helping in the identification and classification of soil are presented and discussed below. The soils are classified and identified based on index properties. Table 1 shows consistency limits (atterberg limits) results for the three soil samples tested. After lime application, the plasticity decreases (as can be seen in figure 1-untreated vs lime treated soil samples).

3.1.1Consistency limits

Table 1: Consistency index properties of the soil

Property	Sample 1	Sample 2	Sample 3
Liquid limit (%)	32	23.43	22
Plastic limit (%)	21.25	10.61	11.31
Linier shrinkage (mm)	4.21	4.24	3.89
Plasticity index (raw) (%)	10.98	12.82	10.68
Plasticity index (Lime-treated) (%)	8.42	10.72	7.61

3.2.1Grading analysis of the soil

Figure 1, 2 and 3 shows the grading curves for sample 1, 2 and 3 respectively of acidic nature. According to the grading analysis on the three soil samples indicated that sample one is a well graded soil containing particles of a wide range of sizes and has a good representation of all sizes. The remaining two samples being the semi-well graded soil samples as per the grading analysis test.

3.2Engineering/geotechnical properties of lime treated soil

3.2.1Maximum Dry Density (MDD) & Optimum Moisture Content (OMC)

An analysis on the maximum dry density and the optimum moisture content of the lime treated three soil samples at different contents of lime performed to determine the relationship between the moisture content and the dry density of a soil for a specified comp active effort was conducted. The result of series of tests conducted to examine the impact of different lime contents at 2%, 4%, 6%, 8% and 10% on the ASSTHO Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) are presented in table 2.

The results of the compaction tests conducted on the soil samples showed that the addition of lime resulted in the improvement in the characteristics of the natural three soil samples. The three soil samples displayed their respective maximum dry densities ranging from 1600 kg/m³ to 1900 kg/m³ and their respective optimum moisture contents ranging from 14% to 20%. With constant comp active effort, the addition of different lime contents indicated highest values of the MDD with corresponding values of OMC for sample # 3 at lime content of 4% by weight of soil. For samples 1 and 2, results showed that further addition of lime decreases the density with constant or increasing moisture content.

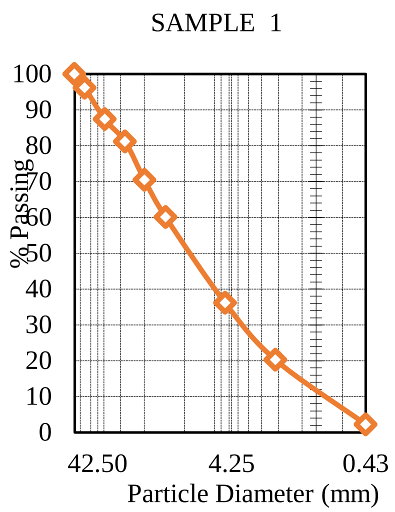

Figure 1: Particle size distribution for sample one

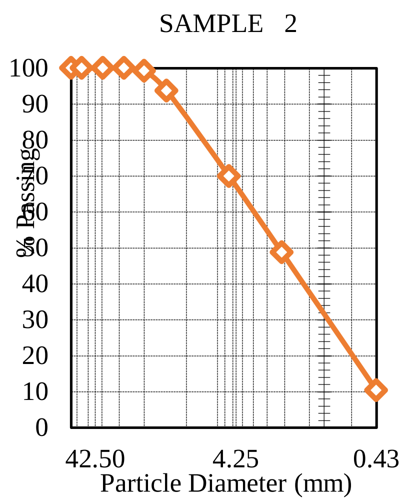

Figure 2: Particle size distribution for sample two

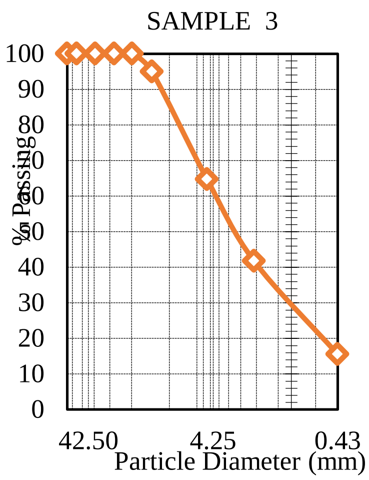

Figure 3 : Particle size distribution for sample three

Table 2: Maximum Dry Density and Optimum Moisture Contents of lime stabilized soil sample.

Sample Number	Property	2% Lime	4% Lime	6% Lime	8% Lime	10% Lime
1	Maximum Dry Density (MDD kg/m³)	1702.8	1702.8	1740.6	1749.2	1672
	Optimum Moisture content (OMC %)	20	20	20	20	19
2	Maximum Dry Density (MDD kg/m³)	1667.2	1643.0	1670.1	1677.35	1645.59
	Optimum Moisture content (OMC %)	22	20	20	20	20
3	Maximum Dry Density (MDD kg/m³)	1834.4	1937.3	1811.3	1899.9	1792.7
	Optimum Moisture content (OMC %)	15	14	21	14	17

Lime content at range of 4% - 6% indicates density increase of the stabilized soil samples. The dry density of the soil samples showed a decrease with increase in lime content of 10%. Ajayi (2012) once reported that the above situation (i.e. the increase in the moisture content vs decrease in dry density in relation to the addition of lime) results from lower amount of compaction or less comp active effort.

Generally, the addition of lime to soil increases the optimum content and lowers the maximum dry density as lime content increases.

2.2 Unconfined compressive strength of lime stabilized soil

The unconfined compressive strength test was conducted to determine the undrained strength of the soil samples tested under unconfined conditions according to the Technical Methods of Highway 1 (TMH1) and other soil science standards.

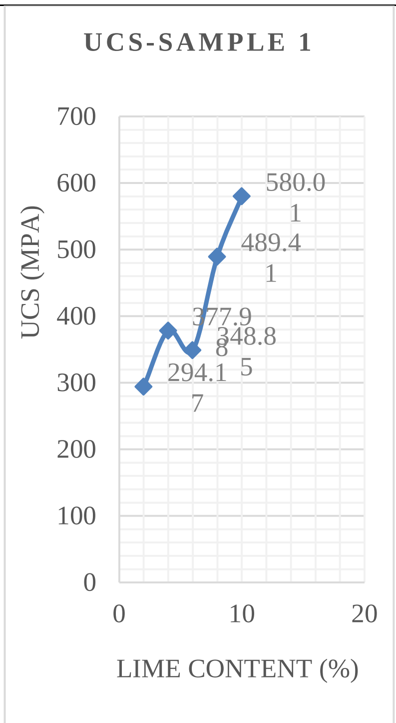

Figure 4: Sample 1 UCS @ 2%, 4%, 6%, 8% & 10% lime contents at 7th day of curing.

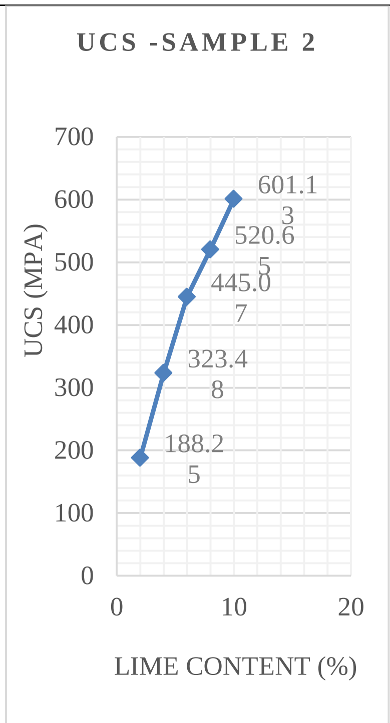

Figure 5: Sample 2 UCS @ 2%, 4%, 6%, 8% & 10% lime contents at 7th day of curing.

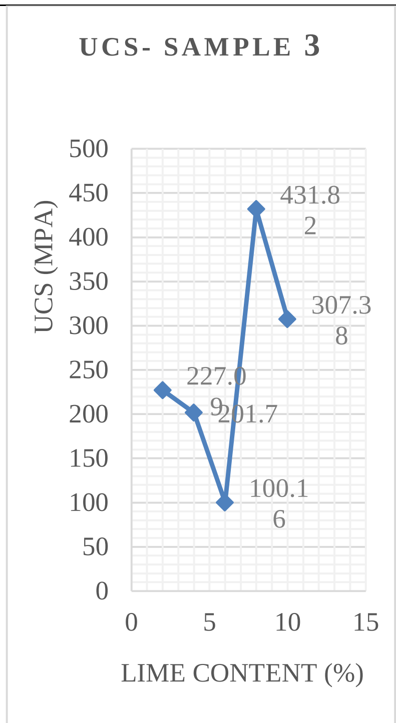

Figure 6: Sample 3 UCS @ 2%, 4%, 6%, 8% & 10% lime contents at 7th day of curing.

The result of the Unconfined Compression Strength test conducted on the three naturally occurring acidic soil samples stabilized with 2% 4% 6% 8% and 10% lime contents, compacted at the respective MDD and OMC, and cured for seven days in accordance with TMH1 (1996) are shown in Figure 4, 5 & 6 respectively.

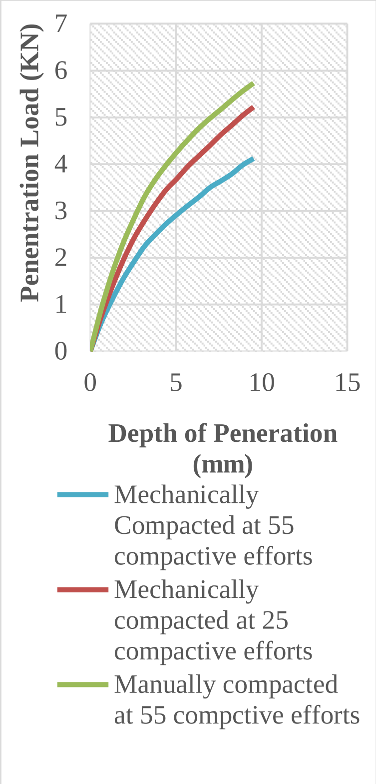

Figure 7: Sample number 1 @ 2% lime usage cured for seven (7) days

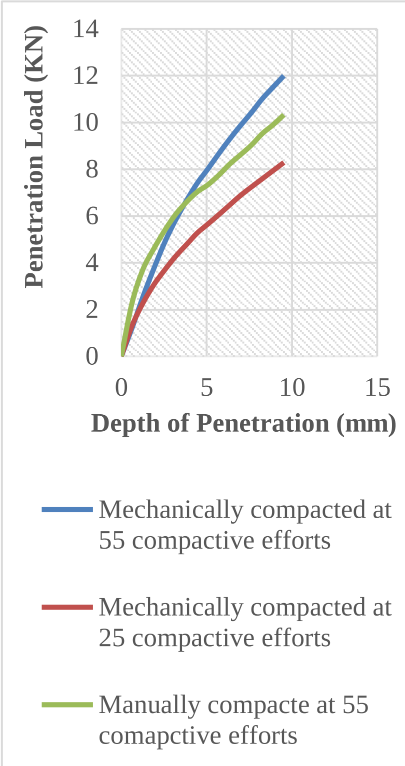

Figure 8: Sample number 1 @ 4% lime usage cured for seven (7) days

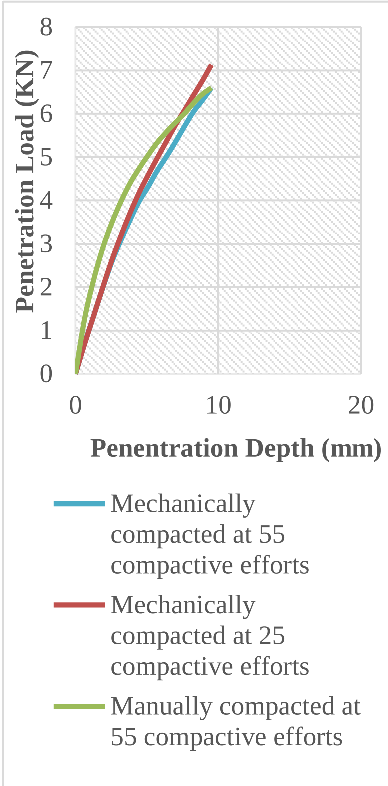

Figure 9: Sample number 1 @ 6% lime usage cured for seven (7) days

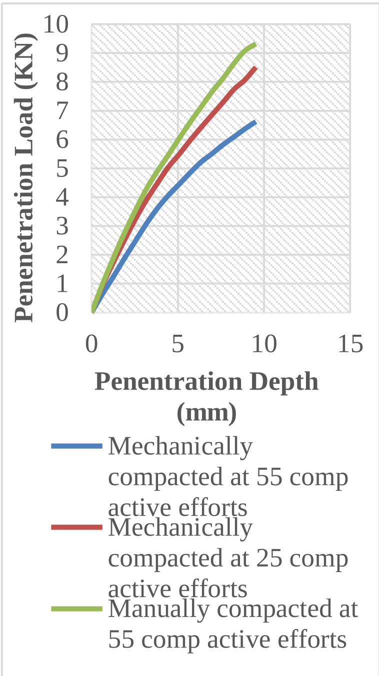

Figure 10: Sample number 1 @ 8% lime usage cured for seven (7) days

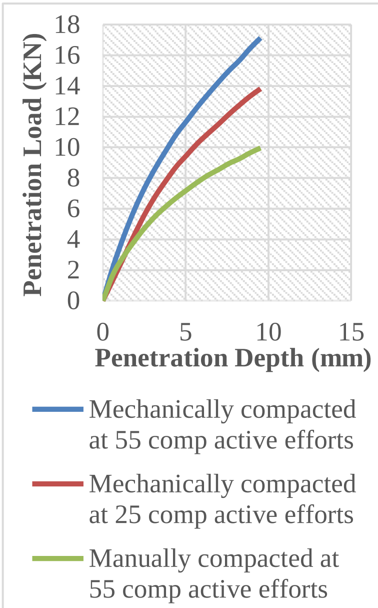

Figure 11: Sample number 1 @ 10% lime usage cured for seven (7) days

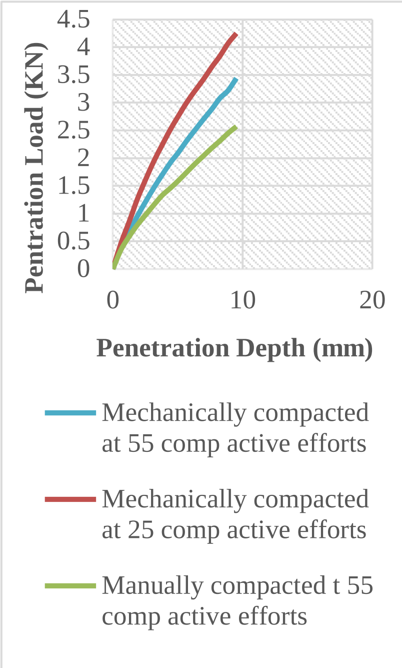

Figure 12: Sample number 2 @ 2% lime usage cured for seven (7) days

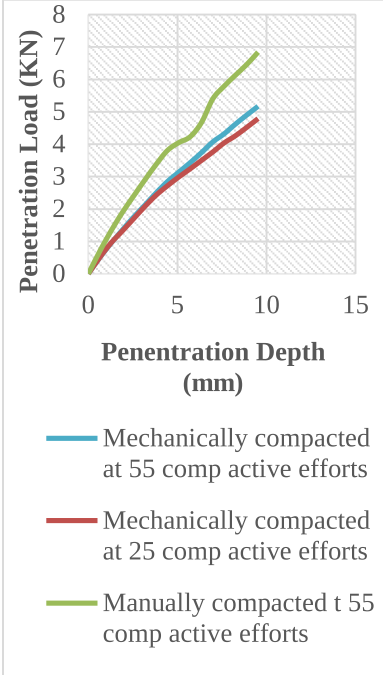

Figure 13: Sample number 2 @ 4% lime usage cured for seven (7) days

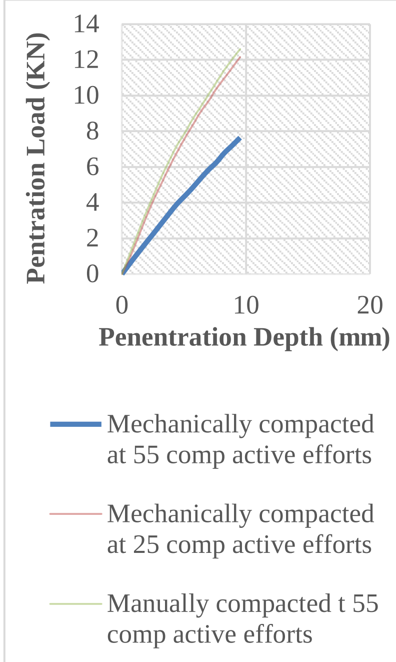

Figure 14: Sample number 2 @ 6% lime usage cured for seven (7) days

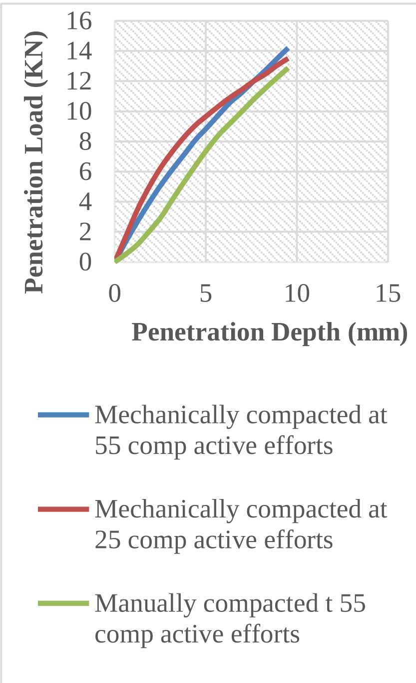

Figure 15: Sample number 2 @ 8% lime usage cured for seven (7) days

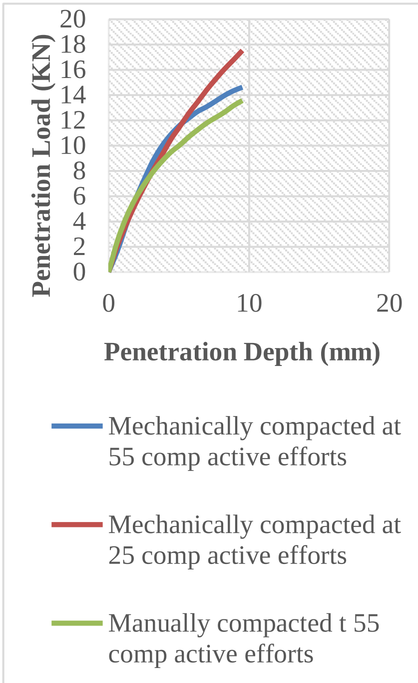

Figure 16: Sample number 2 @ 10% lime usage cured for seven (7) days

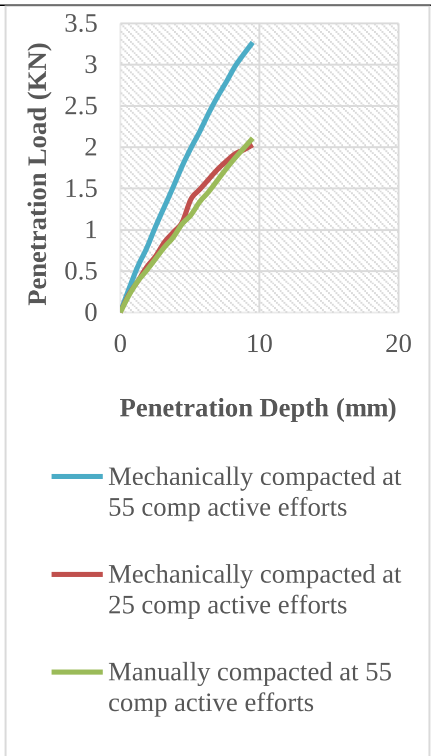

Figure 17: Sample number 3 @ 2% lime usage cured for seven (7) days

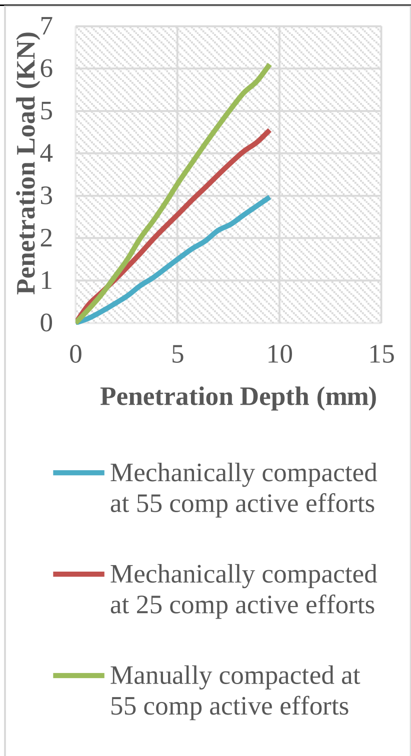

Figure 18: Sample number 3 @ 4% lime usage cured for seven (7) days

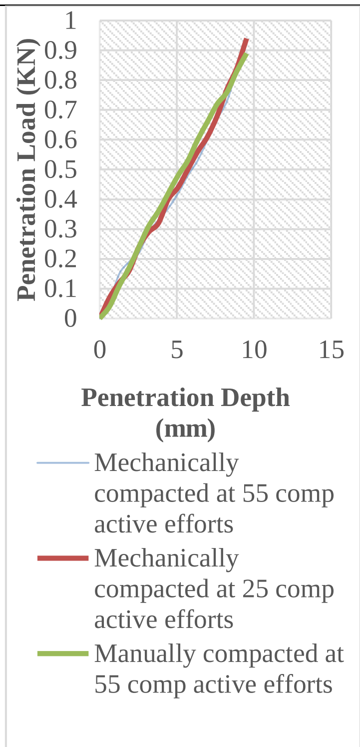

Figure 19: Sample number 3 @ 6% lime usage cured for seven (7) days

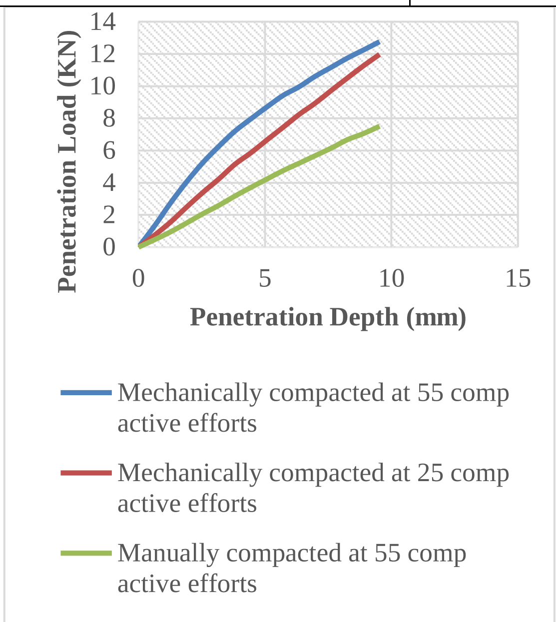

Figure 20: Sample number 3 @ 8% lime usage cured for seven (7) days

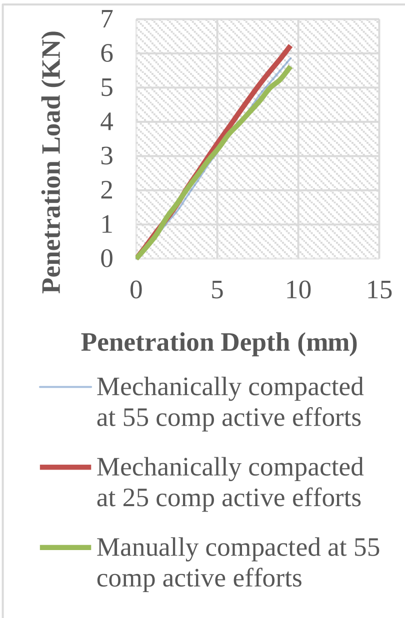

Figure 21: Sample number 3 @ 10% lime usage cured for seven (7) days

The results indicate that the UCS (one engineering property of the soil) of the soil sample can be significantly improved by lime stabilization. Constant increase in strength was indicated by the lime stabilized material for sample 2 at each lime content with highest strength recorded at lime content of 10% after curing for seven days. Sample 1 and 2 indicated a slow grow in strength compare to sample two and a decrease UCS of the soil when treated with lime content of 6%. This may be from a number of contributory factors, one which has to do with the testing methodology of the soil sample and perhaps problems relating loss of cementitious content in stabilized soils (carbonation) taking place while soil samples were mixed lime is mixed with lime and moist soil in the open air.

2.3California Bearing Ratio Penetration (CBR Penetration)

The California bearing ratio (CBR) test was conducted by measuring the load required to penetrate surface of the compacted soil samples, at different comp active efforts (i.e. 55 CBR mechanically compacted, 25 CBR mechanically compacted, and 55 CBR manually compacted).

The results of the CBR tests on lime contents of 2% 4% 6% 8% and 10% for all soil samples are shown in Figure 7 to Figure 21.

Lime treated soil samples at 25 comp active efforts recorded lower CBR compare to the soil samples at 55 comp active efforts for almost soil samples.

The constant increase in the CBR values (as shown by figure 7-21) for almost all the tested soil samples in a direct indication of the principal chemical reactions taking place during lime-soil stabilization (Aldaood, Bouasker and Mukhtar, 2014) namely Cation exchange, flocculation and agglomeration, lime carbonation, pozzolanic reaction.

4. Constrains/Limitations of the study

Limitation in this research had relation to the lack of other adequate information having relevance to lime-soil stabilization, particularly the factors such as loss of cementitious content in stabilized soil leading to the formation of calcium carbonate when lime treated soils are in the open air is might have promoted by carbonation.

5. Conclusions

Important engineering properties of soils can be improved by the addition of lime. The properties vary and relies upon the type of soil used. In understanding the possible mechanisms associated with lime-soil stabilization, a series of experiments through variation of properties were conducted in a laboratory setting, and the following conclusions can be drawn from the result of series of tests aimed at studying the influence of lime to the engineering properties of the three soil samples.

The liquid limit of soil decreases with an increase in lime content while the plasticity of soil reduces with increased lime content.

The results of this investigation have shown that beneficial effects are obtained by the use of lime contents to soil samples. The dry density of the soil sample decreases with increase in lime content. The increase in the optimum moisture content due to the addition of lime resulted into lower amount of compaction or less comp active effort.

The result of the Unconfined Compression Strength test conducted on the three naturally occurring acidic soil samples stabilized with 2% 4% 6% 8% and 10% lime contents, compacted at the respective MDD and OMC, and cured for seven days in accordance with TMH1 (1996) indicated that the soil samples can be significantly improved by lime stabilization.

Factors such as loss of cementitious content in stabilized soil leading to the formation of calcium carbonate when lime treated soils are in the open air is might have promoted by carbonation as can be justified by inconsistency of some of the UCS test values.

The CBR test was performed by measuring the load required to penetrate the surface of the compacted soil samples, at different comp active efforts (i.e. 55 CBR mechanically compacted, 25 CBR mechanically compacted, and 55 CBR manually compacted). For all the three tested soil samples treated with different lime contents reported a constant increase in CBR when compacted at 55 comp active efforts. Lime treated soil samples at 25 comp active efforts recorded lower CBR compare to the soil samples at 55 comp active efforts for all soil samples.

The constant increase in the CBR values for almost all the tested soil samples in a direct indication of the principal chemical reactions taking place during lime-soil stabilization.

However it remains to be discovered experimentally the impact of lime on the soil engineering properties of alkaline soil samples as well. These are soils with pH above seven (7). Scientific comparison of the properties of soils of different nature in terms of the degree of acidity and alkalinity might provide a broader or extensive information pertaining to the influence of lime on soils.

6. Recommendations

It will be recommended for the scope of the study to be extended, particularly in getting a broader understanding mitigations relating to factors such as loss of cementitious content in stabilized soil leading to the formation of calcium carbonate when lime treated soils are in the open air is might have promoted by carbonation as can be justified by inconsistency of some of the UCS test values.

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